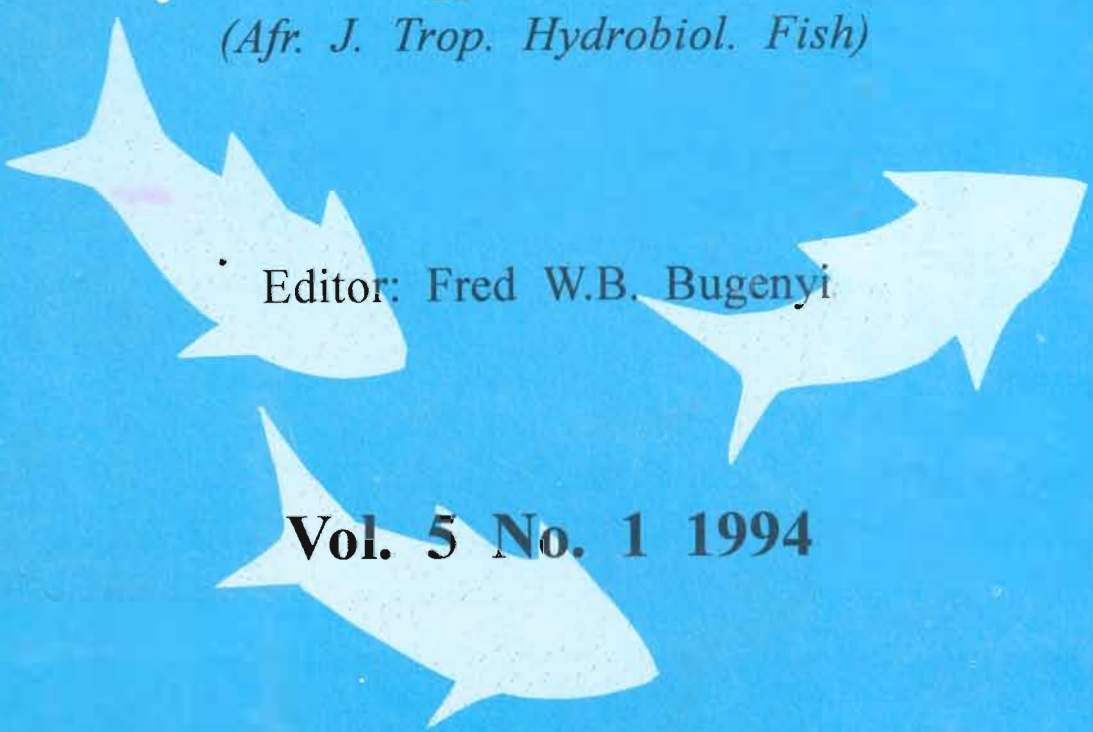
THE AFRICAN JOURNAL OF

Tropical Hydrobiology and Fisheries

(Afr. J. Trop. Hydrobiol. Fish)



Editor: Fred W.B. Bugenyi

Vol. 5 No. 1 1994

The New Vision Printing and Publishing Corporation,
P.O. Box 9815, Tel: 235209, Kampala.

NUTRITIVE VALUE OF FISHES OF LAKE TANGANYIKA: II. MINERAL COMPOSITION

HENDRIK A. DEELSTRA, HENRI NULIENS AND FREDDY ADAMS
Universitaire Inslelling Antwerpen, 2610 Wilrijk, Belgium

ABSTRACT
The composition of the minerals in three economically important fish species of Lake Tanganyika was determined. From the analyses there does not appear to be significant difference in the composition for the three species. Beside the major elements: Ca, P, K, Na, Mg, Cl, Fe, Al and Zn, eighteen trace elements were determined. The presence of the bones in the fish is especially nutritionally important for the following elements: Ca, P, Br, Sr, Mn and Mg.

INTRODUCTION

Part one of this series of papers presented the information on the amino acid composition of three economically important fish species of Lake Tanganyika, representing 95% of the total catch (DEELSTRA, et al. 1974). In the present paper primary attention is focussed on the mineral composition of these fishes.

In general the mineral constituents of fish are studied much less than nitrogenous compounds and lipids. Only a few elements have been subject to analysis, particularly phosphorus, calcium and iron. The majority of the analyses apply exclusively to fish meat (CAUSERET, 1962).

The knowledge of the mineral composition of the whole fish remains mostly deficient, although whole fish is consumed to a great extent by several populations of Asia, Africa and Latin America and form an important part of the "usual village diet". Efforts have been made in numerous countries, often with the technical support of international organisations, to expand the consumption of small fish eaten whole under different forms. These efforts are of great value not only to ensure the prevention of protein malnutrition, but also to improve the calcium intake by the people. Other elements are also a vital part of human nutrition and serve in body metabol-ism: phosphorus, sodium, potassium, chlorine, magnesium, iodine, copper, sulfur, zinc, cobalt, bromine and fluorine are well established as essential for nutritional well being (UNDERWOOD, 1971). In recent years interest in trace elements and their physiological significance has increased considerably (LEE, 1972).

Finally measurements of trace metal content can be used by biologists to ascertain tolerance levels within fish, which can be used to help make determinations of the cause of eventual "fish kills" due to pollution.

Only scant data are available for some trace elements in fish and fish meal, for example in the work of ANDERSON (1972), DEELSTRA (1972), GAJAN and LARRY (1972), LUND (1968), STRASHEIM et al. (1964).

The fish species of Tanganyika lake representing 95% of the total catch are two small clupeid species: *Stolothrissa tanganicae* REGAN (commonly called dagaa) and *Limnothrissa miodon* BOULENGER (called

lumpu), and a centropomid *Luciolates stapperssi* BOULENGER (called mukeke). These species are endemic to the lake. The clupeid species feed on plant and animal elements of the plankton. *Luciolates* feed on clupeids, perhaps exclusively (COULTER, 1970). Traditionally, the majority (70%) of the clupeids are sundried and eaten whole.

EXPERIMENTAL PROCEDURE

Pretreatment of the samples

Samples of fish were obtained from the catch at the mouth of the Ruzizi River, during the rainy season (April-May). All the fish species were wholly dried on cement floors in the sun for two or three days. The clupeids were adult species, the luciolates were young species of the same size as the clupeids.

The average percentage moisture lost by drying in the sun was approximately 75%. The samples were ground in a mixer and dried to constant weight for 48 hours at 110°C.

A study on ways of destroying organic material has shown that dry ashing at 400°C is very satisfactory for the analysis of traces of inorganic constituents (GORSUCH, 1970; CHRISTIAN, 1969). A study by ANDERSON (1972) about the comparison of the wet digestion method versus the dry ashing method for the analysis of zinc, chromium, copper, cadmium and lead in fish tissues did not show significant loss for the dry ashing method at 500°C. This method is much less time consuming, has recoveries comparable to the wet digestion method and better precision. GAJAN and LARRY (1972), in a collaborative study with nineteen laboratories, made the same observation for lead determination. JUISHAM and BRAEKKAN (1973) did not find losses by volatilization in the determination of cobalt by dry ashing at 480°C.

Dried samples were placed in porcelain evaporating dishes and ashed in a muffle furnace at 400°C overnight for 16 hours. Composition may vary from fish to fish so the ash of at least 50 fish was combined. The ash was directly used for the neutron activation analysis; samples of 4 to 20 mg were taken. For the other analysis the ash was dissolved in 5 ml concentrated nitric acid p.a. After standing for approximately one hour, the samples were transferred to 100 ml volumetric flasks and diluted to volume with deionized water.

To obtain flesh-free bones, the fishes are steamed in polyethylene bags and then separated by hand. After drying at 110°C they are ashed at 400°C in the same way as the dried fishes.

The residual moisture in the sundried fish and the ash content of the fish and the bones are presented in Table I.

Table 1. Residual moisture and ash content of sundried Lake Tanganyika fish

	Residual Moisture (at 110°C)%	Ash %
Stolothrissa tanganicae	8.3	15.7
Limnothrissa moidon	9.9	15.1
Luciolates stappersii	8.8	14.9
Bones of *Stolothrissa tanganicae*	—	40.0

Neutron Activation Analysis:

The neutron activation analyses were carried out in the Thetis reactor at the Institute for Nuclear Science of the University of Ghent, Belgium. An instrumental neutron activation method was applied based on two irradiations at $^{+}10^{12}$n.cm.$^{-2}$ sec^{-1} and several measurements with a high resolution Ge(Li) gamma-ray detector. After a short irradiation of 5 min. measurements were performed during 10 min. after a waiting time of 2 min. for the specific detection of Al, Br, Ca, Cl, Cu, Dy, I, In, Mg, Mn, Na, Ti, V through the use of short-lived radioisotopes. A 6 h irradiation with a measurement during 1 hour 24 hours after irradiation allowed the measurement of Au, As, Ba, Br, Cd, Cu, Eu, Ga, In, K, La, Mo, Na, Sm, W, Yb, Zn and another measurement during 6 hours 3 weeks after the irradiation allowed for Ag, Ba, Ce, Cr, Cs, Co, Eu, Fe, Hf, Hg, Ir, Lu, Ni, Rb, Se, Sb, Sc, Th, Yb, Zn.

The samples were brought to aluminium disks and covered with polyethylene tape for the measurements. A true coaxial Ge(Li) detector with a 5.5% efficiency was used (ORTEC 8001). The detector was connected to an ORTEC 120 preamplifier and ORTEC 450 research pulse amplifier. A BM 96 4096 channel memory and 4096 channel 20 MHz ADC from Intertechnique were also used. The characteristics of the spectrometer are: energy resolution 2,3 KeV FWHM 4,5 KeV FWTM, a peak-to-Compton ratio of 23:1 all at 1.33 MeV. All measurements were performed in a 5 cm thick lead castle. Spotted amounts of different elements on Whatman 41 filter paper were used as a comparator. For the short-lived activities a flux monitor was used to correct for neutron flux variations.

A PDP 9 computer was used for the quantitative analysis of the complex gamma-ray spectra. Isotopes from the above mentioned elements were specifically searched for and the peak activity of one of the major gamma transitions was measured and compared with the same radiation in a comparator spectrum. Corrections were applied for differences in neutron flux, geometry, counting time etc. whenever necessary.

The concentration of a number of trace and other constituents was calculated. The standard deviation on the results can be estimated at $^{+}5\%$ plus the counting statistics. A number of elements were specifically searched for but not detected. The detection limits based on three times the square root of the background are published by DAMS R. et al. (1970).

Atomic Absorption Spectrometry

All measurements were carried out on a Perkin Elmer model 103 atomic absorption spectrometer using a single slot burner head and the standard operating conditions of PERKIN and ELMER (1972).

For absorption and emission methods the calibration curve method as well as the standard addition method was used.

In order to evaluate the presence of some toxic, volatilizable metals at low concentration (Pb, Cd) the sampling boat method described by HOLAK (1973) was used. In this method 0.5 ml sample is added to the tantalum boat, dried and atomized into the light path by the thermal energy of the flame. A sharp narrow absorption signal is recorded on a Perkin-Elmer Model 56 Recorder.

Other methods

Phosphorus was determined by a colorimetric method proposed by VOGEL (1971); Fluoride with the ionselective electrode of ORION, using the method of KE et al (1970). Chloride was controlled by potentiometric titration (VOGEL, 1971).

Results and Discussion

Table 2 gives the results of the analysis for the mineral constituents in the three species expressed in mg/100 g of sundried fish determined by neutron activation analysis (N.A.A.), by flame spectrometry

Table 2. Mineral content (mg per 100 g of sundried fish) of three fishes from Lake Tanganyika. N.A.A. — Neutron activation analysis. F.S. — analysis by flame spectrometry. N.D. — Not detected.

Mineral	*Stolothrissa*		*Limnothrissa*		*Luciolates*	
	N.A.A.	F.S.	N.A.A.	F.S.	N.A.A.	F.S.
Ca	4076.	3650.	4200.	3324.	3516.	3307.
Mg	217.	184.	203.	187.	210.	177.
Na	396.	390.	389.	326.	390.	369.
K	1287.	1235.	1408.	1381.	1564.	1400.
Fe	31.5	24.8	—	12.7	20.8	12.6
Al	18.1	—	11.1	—	10.6	—
Zn	17.1	18.6	14.9	14.5	11.2	11.9
Rb	—	3.45	—	2.87	—	4.02
Mn	2.53	2.08	1.72	1.93	1.28	0.86
Ni	2.36	0.62	2.31	0.83	3.41	0.89
Cu	1.38	1.01	1.15	0.77	1.28	0.64
Mo	1.12	—	2.41	—	3.26	—
Sr	—	1.03	—	1.07	—	2.05
Cr	0.71	0.25	0.78	0.24	1.07	0.24
Pb	—	0.23	—	0.45	—	0.44
V	0.096	—	0.013	—	0.017	—
Cd	—	0.047	—	0.012	—	0.006
Co	0.027	—	0.049	—	0.050	—
Sb	0.025	—	0.013	—	0.035	—
Cs	0.014	—	0.021	—	0.024	—
Th	0.010	—	0.018	—	0.118	—
Sc	0.005	—	0.005	—	0.003	—
OTHER METHODS						
P	—	2869.	—	2720.	—	2860.
Cl	122.	109.	209.	194.	86.5	90.8
Br	1.50	—	3.88	—	1.59	—
F	—	2.88	—	2.07	—	0.96
As	0.75		N.D.	—	1.04	—

(F.S.): atomic absorption spectrometry (A.A.A.) and by flame emission spectrometry (F.E.S.) and by the other mentioned methods.

Table 3 gives the results of the analysis of the bones of *Stolothrissa* in mg/100 g of sundried fish. The results of the N.A.A. are the average of four separate analyses, the standard deviation indicate a good precision. The values for the flame spectrometry are the average of the results obtained by the calibration procedure and the standard addition technique.

Table 3. Mineral content in mg per 100 g of sundried bones of *Stolothrissa tanganicae*. (N.A.A. — Neutron activation analysis. F.S. — Analysis by flame spectrometry N.D. — Not detected.)

Mineral	N.A.A.	F.S.	% in whole sundried fish
Ca	509.	558.	13.8
Mg	14.5	12.7	6.8
Na	8.25	9.65	2.3
K	3.27	3.92	0.3
Fe	1.00	0.30	2.3
Al	0.78	—	4.3
Zn	0.96	0.79	4.9
Rb	—	N.D.	
Mn	0.266	0.246	11.1
Ni	N.D.	0.025	1.7
Cu	0.081	0.014	4.0
Mo	N.D.	—	
Sr	—	0.254	24.5
Cr	0.052	0.024	7.9
Pb	—	0.007	3.0
V	0.007	—	7.3
Cd	N.D.	0.0004	0.9
Co	N.D.	N.D.	
Sb	0.003	—	12.0
Cs	0.001	—	7.1
Th	N.D.	—	
Sc	0.001		
OTHER METHODS			
P		275.	9.6
Cl	1.03	—	0.9
Br	0.68	—	45.7
F	—	0.138	4.8
As	0.010	—	1.3

In general the composition of mineral constituents for the three species analysed compared to each other is uniform.

The percentage of elements in the whole fish coming from the bones is given in the last column of Table 3. It is clear that the presence of the bones in the fish is especially important for calcium, phosphorus, bromine, strontium, manganese and magnesium, while elements as potassium, chlorine, sodium, iron seem to come essentially from the boneless fish.

The analysis of the whole fish indicates large amount of calcium, magnesium, phosphorus, sodium and potassium. The calcium/phosphorus ratio varies between 1.18 and 1.54. According to the literature the ratio in flesh varies between 0.05 and 0.6, with an average of 0.2 (CAUSERET, 1962). The ratio found by DA COSTA and STERN (1956) in plain canned sardines (members of the clupeideae) was shown to be approximately unity in all samples regardless of country of origin. The value of this ratio for the bones is nearly 2. The bones contain close to one seventh of the calcium of the fish and a tenth of its phosphorus. This is in accord with the results found by DA COSTA and STERN (1956).

The richness in calcium in the fish is not only due to the bones, but the skin and the scales are essentially responsible for the high content of this element. PERISSE and LE BERRE (1957) in a study of various species of fish of Togo confirmed the importance of the scales in small sized species of fish. The calcium content in these whole fish are comparable with the results in Table 3. This calcium, represented as calcium phosphates, is well utilized by the body as demonstrated by BASU (1942).

The ratio of the sodium content to that of potassium is similar to the ratios found by THURSTON (1958) in the flesh of different fish species, roughly one part by weight of

sodium to four parts of potassium.

CONCLUSION

Three dried fish species of Lake Tanganyika have been analyzed for their mineral constituents. In general the mineral composition of these species was uniform and shows, compared to the minerals supplied by an average diet, an important source for calcium, phosphorus, potassium, iron, copper and fluorine.

The bones contain an important part of calcium, magnesium and phosphorus. The three fish species traditionally consumed whole are, thus very effective dietary source of these minerals.

REFERENCES

Anderson, J. (1972). Wet digestion versus dry ashing for the analysis of fish tissue for trace metals. *Atom. Abs. Newsletter,* 11, 88

Baetz, R.A. and C.T. Kenner, (1973). Determination of Heavy metals in foods. *Agric. and Food Chem.,* 21, 436

Basu, K.P., H.N. De and M.N. Basak, (1942). Studies in Human nutrition. 5. The bones of small fish as a source of nutritionally available calcium and phosphorus. *Indian J. Med. Research.,* 30, 417.

Bergeret, B and R. Masseyeff, (1957). Table provisoire de composition des aliments de Sud-Cameroun. *Ann. Nutrition et Aliment,* 11, 47.

Causeret, J. (1962). Fish as a source of Mineral Nutrition p. 205-234. In *Fish as Food,* (ed) G. Brogstrom, Academic Press, New York.

Christian, G.D., (1969). Medicine, Trace elements and atomic absorption spectroscopy, *Analytical Chemistry,* 41, 24 A.

Coulter, G.W. (1970). Population changes within a group of fish species in Lake Tanganyika following their exploitation. *J. Fish. Biol.,* 2, 329.

Dams, R., J.A. Robbins, K.A. Rahn and J.W. Winchester, (1970). Non-destructive neutron activation analysis of air pollution particulates. *Analytical Chemistry,* 42, 861.

Da Costa, A. and Ja.A Stern, (1956). The calcium and phosphorus content of some foreign and domestic canned sardines. *Food Research,* 21, 242.

Deelstra, H. (1972). L'electrode sensible aux ions fluorures. Applications au Burundi, *Revue Univ. du Burundi,* 1, 1,

Deelstra, H.A., O. White, and D.S. Wiggans, (1974). Nutritive value of fish of Lake Tanganyika, I. Amino acid composition. *Afr. J. Trop. Hydrobiol. Fish.* 3(2): 161-166

Gajan, R.J. and D. Larry, (1972). Determination of Lead in Fish. *Journ. Assoc. Off. Anal. Chem.,* 55, 727.

Giron, H.C. (1973). Comparison between dry ashing and wet digestion. *Atom. Abs. Newslett.,* 12, 28.

Gorsuch, T.T. (1970). *The destruction of organic matter,* Pergmon Press, New York.

Holak, W. (1973). Determination of lead and cadmium in foods by atomic absorption spectrophotometry using the "sampling boat". *Atom. Abs. Newslett.,* 12, 63.

Holemans, K. and A. Lambrechts, (1958). Calcium and Phosphorus balances in African children. *J. Trop. Pediatr.,* 4, 43.

Julsham, K. and O.R. Braekkan, (1973). The determination of Cobalt in fish tissue. *Atom. Abs. Newslett.,* 12, 139.

Ke, P.J., H.E. Power and L.W. Regier, (1970). Fluoride content of fish protein concentrate and raw fish. *J.Sc. Fd. Agric.,* 21, 108.

Lee, D.H.K. (1972). *Metallic Contaminants and Human Health.* Academic Press, New York.

Lund, G. (1968). Activation analysis of trace elements in fish meal. *J. Sci. Food & Agr.* 19, 432.

Perisse, J. and Le Berre, (1957). Table de composition des aliments du Togo. *Ann. Nutrition et Aliment.* 11, 70.

Perkin and Elmer (1972). *Analytic Methods for atomic absorption spectrophotometry.*

Strasheim, A, E. NorvalL and L.R.P. Butler, (1964). The determination of traces of lead in fish four. *J. of South Afr Chem. Inst.,* 17, 53.

Thurston, C.E. (1958). Sodium and potassium content of 34 species of fish. *J. Am. Dietet. Assoc.* 32, 396.

Underwood, E.J. (1971). Trace Elements in Human and Animal Nutrition, 3rd ed., Academic Press, New York.

Vogel, A.L. (1971). A textbook of Quantitative Inorganic Analysis, 3rd. ed. Longman, London, p 810 and p 950